

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

METHODS AND RESULTS OF BOUNDARY LAYER MEASUREMENTS ON A GLIDER

Wilhelm Van Nes

(NASA-TM-75294) METHODS AND RESULTS OF
BOUNDARY LAYER MEASUREMENTS ON A GLIDER
(National Aeronautics and Space
Administration) 12 p HC A02/MF A01 CSCL 01A

N78-24085

Unclas
G3/02 21225

Translation of "Bericht über Messmethoden und Messergebnisse
bei Flugmessungen in der Grenzschicht,"
Der Wissenschaftlichen Gesellschaft für Luftfahrt E.V.,
Jahrbuch, 1961, pp. 255 - 259.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546
MAY 1978

1. Report No. NASA TM 75294	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle METHODS AND RESULTS OF BOUNDARY LAYER MEASUREMENTS ON A GLIDER		5. Report Date May 1978	
		6. Performing Organization Code	
7. Author(s) Wilhelm Van Nes Leichtbau and Flugtechnik GmbH, Duisburg		8. Performing Organization Report No.	
		10. Work Unit No.	
9. Performing Organization Name and Address Leo Kanner Associates Redwood City, California		11. Contract or Grant No. NASW-2790	
		13. Type of Report and Period Covered Translation	
12. Sponsoring Agency Name and Address National Aeronautics and Space Adminis- tration, Washington, D.C. 20546		14. Sponsoring Agency Code	
15. Supplementary Notes Translation of "Bericht über Messmethoden und Messergebnisse bei Flugmessungen in der Grenzschicht," Der Wissenschaftlichen Gesellschaft für Luftfahrt E.V., Jahrbuch, 1961, pp. 255 - 259. (A63-21852)			
16. Abstract This paper deals with methods and results of boundary layer measurements. These measurements were carried out in a glider, i.e. under natural conditions. The paper continues the survey presented at the WGL Meeting in Essen in 1957. Two effects are investigated: the effect of inconstancy of the development of static pressure within the boundary layer ($\partial p / \partial y \neq 0$) and the effect of the negative pressure difference in a "sublaminar" boundary layer. The results obtained by means of an ion probe in parallel connection confirm those results obtained by means of a pressure probe. Additional effects which have occurred during these measurements are briefly dealt with.			
17. Key Words (Selected by Author(s))		18. Distribution Statement Unclassified-Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 11	22. Price

METHODS AND RESULTS OF BOUNDARY LAYER MEASUREMENTS ON A GLIDER

Wilhelm Van Nes
Leichtbau and Flugtechnik GmbH, Duisburg

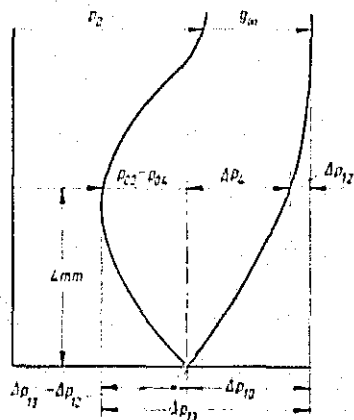
At the 1957 WGL Meeting in Essen I reported on boundary layer measurements made on a glider [1]. Today I would like to discuss refinements in measuring methods which we have made in the meantime and the new results these have yielded.

/255*

Two effects, in particular, are puzzling:

The first is that the results on the static pressure curve within the boundary layer, which according to the theory is supposed to be constant and equal to the static pressure of the outer flow, do not confirm this simplifying assumption of the theory. I have already briefly referred to this in the paper I gave in Essen.

In order to detect this effect we proceeded as follows: the pressure difference was on the one hand determined directly with a manometer and on the other hand it was calculated by adding the measured partial pressures:



Basic diagram.

$$\begin{aligned} \Delta p_{13} &= \Delta p_{10} - p_{00} - p_{01}, \\ \Delta p_1 &= g_1 - p_{00}, \\ \Delta p_{12} &= g_2 - g_1 \end{aligned}$$

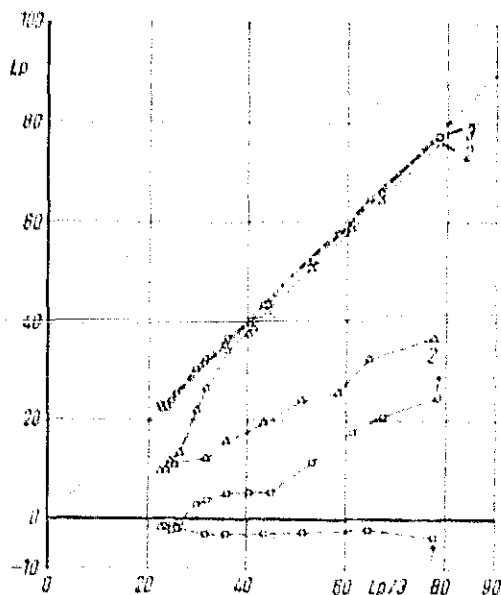
The measurements clearly showed the following:

With a turbulent boundary layer the first summand $p_0 - p_{04}$ is approximately zero and maintains this value over the entire velocity

* Numbers in the margin indicate pagination in the foreign text.

range with a laminar boundary layer, however, the difference changes more or less linearly with the air speed.

Fig. 1 shows the curve of partial pressures as a function of the air speed. In this graph the solid lines represent the partial pressures and their sum in the case of a laminar boundary layer. The broken lines show



The broken lines show the partial pressures for a turbulent boundary layer. The turbulence was caused by a trip wire on the nose. The measurement point was the same for both flights. The tendency of the shape of the pressure curves was always the same. The results were clearly reproducible.

The result is actually not surprising: the transition of the boundary layer into the outer flow occurs asymptotically. At this point, which is not exactly defined in physical terms, there must be a discontinuity in the static pressure curve if $\partial p / \partial y$ were equal to zero in the region of the boundary layer.

The measurements were expanded in the summer of 1961 so that the static pressure curve in the vertical direction was determined by 5 static probes. Evaluations up to that time had clearly shown the difference in

Fig. 1. Flight no. 5, Sept. 11, 1959 (—), laminar boundary layer, Sk. (4) 40; and flight no. 9, Sept. 14, 1959 (---), turbulent boundary layer, Sk. (4) 40 with trip wire at 2.5%.

Curve 1 (□): difference in static pressures at $y = 0$ and $y = 4$ mm;

Curve 2 (Δ): curve 1 + dynamic pressure at $y = 0$ mm;

Curve 3 (○): curves 1 + 2 + difference in total pressures at $y = \infty$ and $y = 4$ mm.

Sk. (4) 40 denotes probe adjustment in position 4 on the test surface, probe at scale division 40. the x/l location of the probe is indicated.

Abscissa: local pressures; ordinate: pressures in the boundary layer. L_p are the measured pressure differences.

the curve in the turbulent and laminar regions.

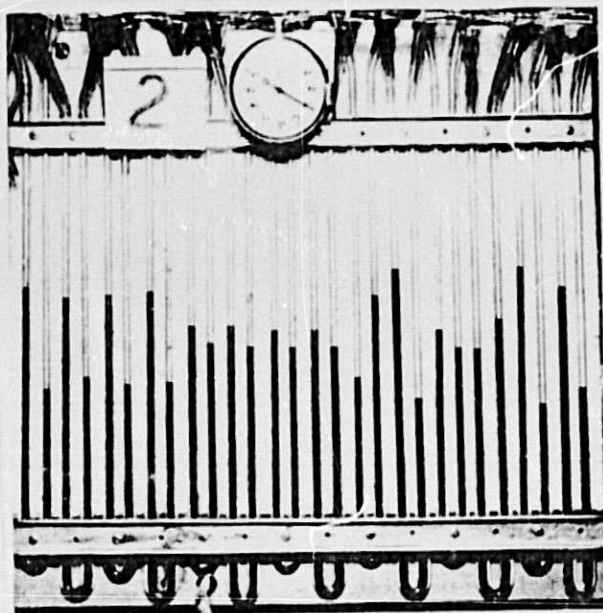


Fig. 2. Manometer panel photograph of flight no. 4, 9/10/59.

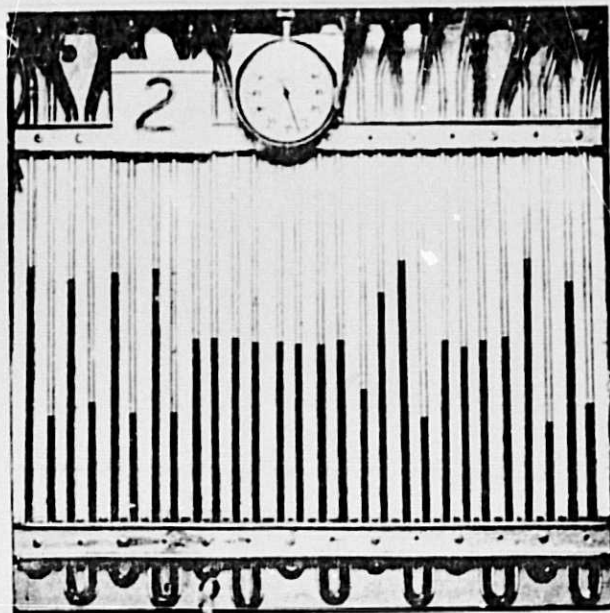


Fig. 3. Manometer panel photograph of flight no. 4, 9/10/59.

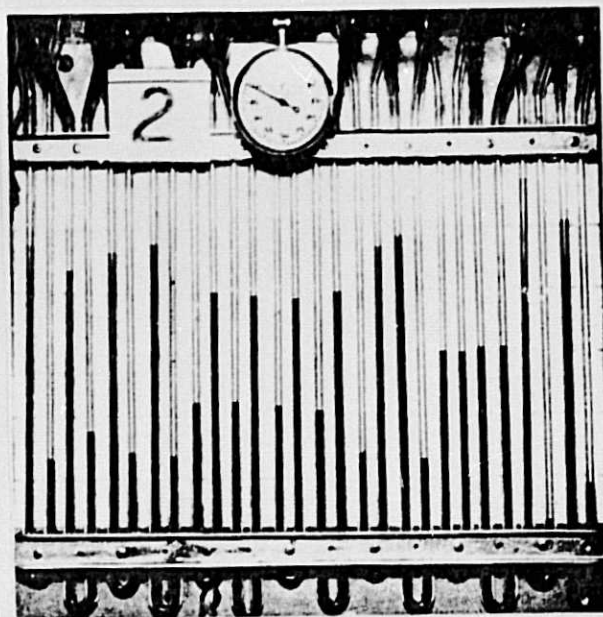


Fig. 4. Manometer panel photograph of flight no. 4, 9/10/59.

The second puzzling effect, namely the pressure reversal in layers close to the wall, was of course already known at the time of the Essen WGL Meeting, but at that time we still had too little data to publish any results. I first referred to this effect at a WGL discussion meeting in Duisburg in 1959 and showed a number of manometer panel photographs. Some of these photographs are shown below. Note the variation in manometers 1-4 and 5-8 and also that of manometer 12 (Figs. 2-4).

Manometers 1-4 were connected to four pitot tubes which were arranged at a distance of about 4 mm from the surface and at intervals of 15 mm in the wing span direction. The right leg of the U-tube is connected to the total

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

to the total pressure and the left leg to the static probe lying on the surface,

The right legs of manometers 5-8 are also connected to the surface pitot tubes and the left leg is connected to the same static probe. Thus under normal oncoming flow conditions the tendency of the reading must be the same in all cases: the right leg must be lower than the left leg.

Manometer 12 measures the pressure difference between the total pressure at infinity and the total pressure at a distance of 4 mm from the surface. There it moves if the boundary layer thickness is greater than 4 mm; if it is less than this, then the response is zero.

Manometer 11 serves as a control. It measures the total pressure of a pair of pitot tubes at a height of 4 mm separated in the chord direction by 35 mm. Thus a significant movement in this manometer may only occur when the transition takes place just between these two probes.

It is clear from the photographs that during a transition of flow from the turbulent to the laminar state an undeniable pressure reversal can be detected on manometers 5-8.

Fig. 5 shows a graphical representation. In this graph the boundary layer velocity at a distance of 4 mm from the wall and the velocity in the layer next to the wall are plotted over the local outer velocity. The pressure curves for manometers 11 and 12 are also indicated. The graph shows the suddenness of the pressure reversal with the transition from turbulent to laminar flow.

This effect was detected in hundreds of test flights, even with different surface materials and different profiles. For a physical interpretation of this effect we have set up a

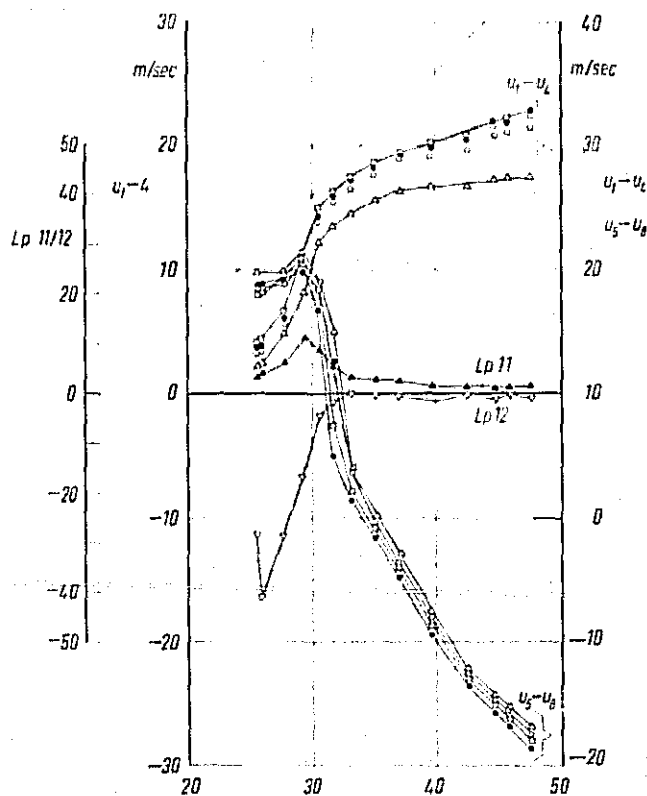


Fig. 5. Flight no. 4, 9/10/59, Sk(4)15.

$$c_{au} = 0,56, \quad c_{wpu} = 0,00824, \quad c_{wpt} = 0,0143, \quad c_{wp} = 0,00606, \\ c_{wpu}/c_{wpt} = 0,424.$$

c_{au} is the c_a value at which the transition occurs.
 c_{wpu} is the drag coefficient pertaining to this c_a value.
 c_{wpt} is the corresponding drag coefficient at full turbulence.
 L_p values are the measured pressure differences.
 Abcissa: local velocity;
 Ordinate: velocities in the boundary layer

	Manometer
□	1 und 5
△	2 und 6
○	3 und 7
●	4 und 8
▲	11
▽	12

Key: und = and

hypothesis, namely that it perhaps involves the overlapping of a normal boundary layer profile by a vortex street rolling in the chord direction over the surface.

From our manometer observations we found that this effect started in the vicinity of the leading edge of the wing where strong unstabilizing effects are to be expected because of the concave curvature of the flow filaments. Therefore at a surface depth of 2.5%, where the manometers showed the greatest fluctuation, we placed

/257

a small perforated tape and applied suction. The result was amazing in two respects. A very small amount of suction was sufficient to considerably influence the development of the boundary layer over the entire measurement range, i.e. from $x/l = 0.075$ to $x/l = 0.375$. However, we also found that an increase in the amount of suction had no noticeable effect. This is shown in Figs. 6 and 7.

The question then arose as to whether this measured effect was real or a trick of our

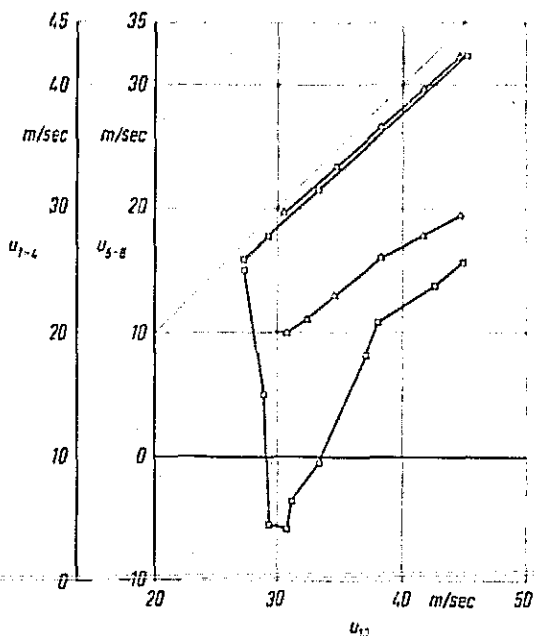


Fig. 6. Flight no. 8, 11/30/58, Sk.(3)10, $\Delta h = 4.0$ mm; without leading edge suction (\square), and flight no. 9, 3/24/59, Sk.(3)10 $\Delta h = 4.0$ mm, with leading edge suction, suction velocity ≈ 40 m/sec (Δ).

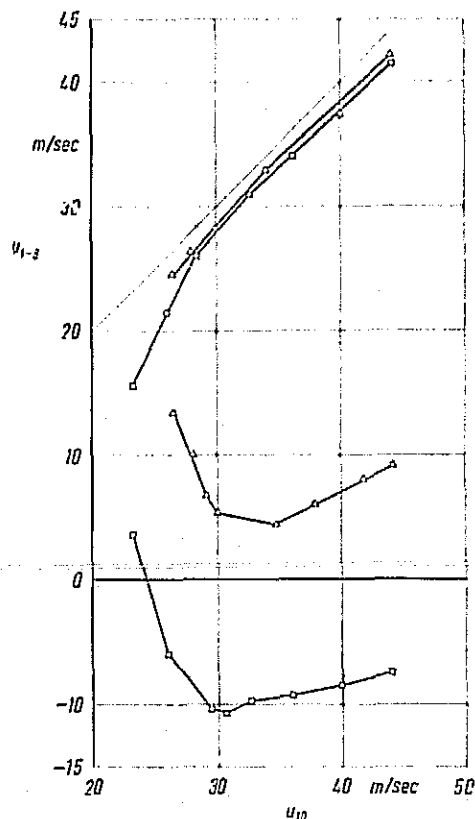


Fig. 7. Flight no. 14, 11/30/58, Sk.(3)40, $\Delta h = 4.0$ mm, without leading edge suction (\square), and flight no. 7, 3/25/59, Sk.(3)40, $\Delta h = 4.0$ mm, with leading edge suction, suction velocity ≈ 40 m/sec (Δ).

measurement apparatus. It was now suggested by ministerial advisor Wahl to measure this effect again using a quite different method, namely by means of the ion probe developed by Prof. Fucks, Prof. Schmitz and Dr. Franzen [2,3].

We performed experiments using this new measurement arrangement. It is based on the following principle: if a voltage is applied to the anode and the cathode of the probe in a normal atmosphere, then either the air acts as an insulator or an arc-over occurs. However, between these two limit states there

/258

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

is an intermediate state, the so-called corona discharge. A positive ion cloud forms at the anode and migrates to the cathode. In this situation the anode consists of a platinum point measuring 5 μ in diameter and the cathode consists of a platinum spear measuring 0.3 mm in diameter. In the course of the measurements the applied voltage was reduced from 2800 V to 1450 V, and in so doing the distance between the electrodes was reduced to about 1.2 mm.

If the electrodes are now exposed to a flow of air, then the amount of ion transport increases if the flow is in the anode-cathode direction. If the flow direction is reversed, the transport is slowed down, i.e. the ion flow is velocity dependent.

Thus we have a d.c. circuit with a constant load resistor and a variable resistor between anode and cathode. Between these two resistors the voltage is conducted to the grid of an amplifier tube and the anode flow of the tube controlled by the grid is measured on a milliammeter.

In addition, a low-frequency pickup connected to the anode circuit through a capacitor so that it was possible to record the corona fluctuations on tape and retain them in an oscillogram. There is not enough room here to go into details.

This method turned out to be practical and it confirmed the back streaming effects -- no longer called "pressure reversal" (Figs. 8 and 9). It should still be mentioned that considerations were necessary, for example to eliminate, by means of connecting a bridge, disturbances caused by air pressure, air humidity and proximity to the surface. Ultimately we used a double probe with two cathodes and one anode in the center. Our studies are continuing along this line. /259

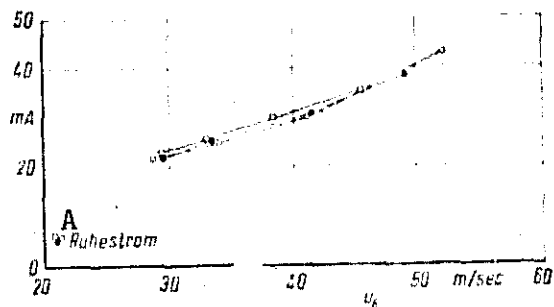


Fig. 8a. Reproducibility of results.

Flight no. 1, 5/9/60, Sk.(4)16,

$\Delta h_k = x_2$ (●),

Flight no. 2, 5/9/60, Sk.(4)16,

$\Delta h_k = x_2$ (□),

Flight no. 3, 5/9/60, Sk.(4)16,

$\Delta h_k = x_2 - 1$ (○).

Δh_k is the distance from the surface of the corona probe.

Key: A) quiescent current

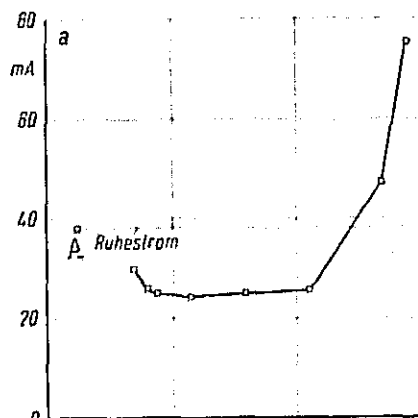


Fig. 9a. Flight no 8, 5/12/60, Sk.(3)22, $\Delta h_k = x_5 - 5.625 \approx 0.2\text{mm}$ (□).

Key: A) quiescent current

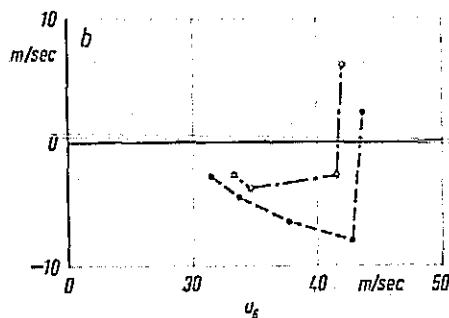


Fig. 9b. Flight no. 14, 9/12/60 (●), Flight no 27, 9/12/60 (○).

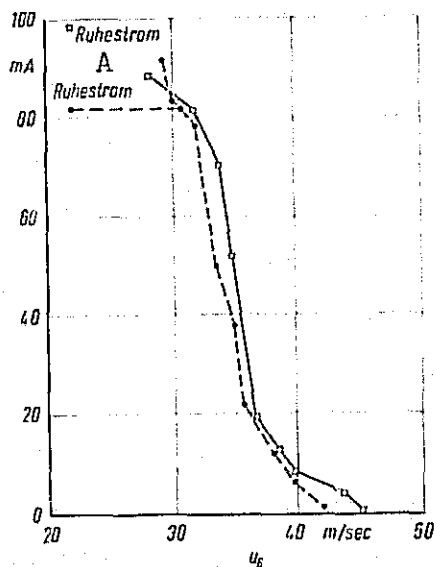


Fig. 8b. Sensitivity and reproducibility of the results. Direction of air flow: cathode-anode.

Flight no. 3, 10/17/60, Sk.(6)20

$\Delta h_k = 0.7\text{ mm}$ (□),

Flight no. 4, 10/17/60, Sk.(6)20

$\Delta h_k = 0.7\text{ mm}$ (●).

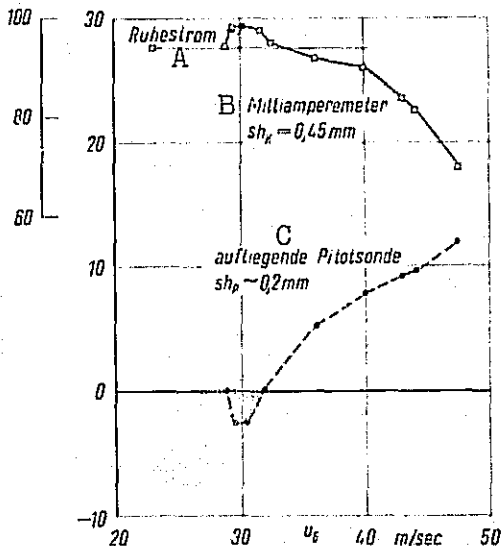


Fig. 9c. Flight no. 9, 9/17/60, Sk.(2)20, $\Delta h_k = 0.45\text{ mm}$, direction of wind flow: cathode-anode.

Key: B) milliammeter

C) surface pitot tube

We also came up with some other interesting findings in our measurements. In the summer of 1960 in Freiburg we recorded a number of tapes with corona fluctuations. When listening to these tapes it turned out that the corona noise was superimposed by the reception of a foreign transmitter, as was obvious from the different languages. Although this did not have anything directly to do with the boundary layer investigations, naturally it interested us and so we investigated the arrangement in place using a test transmitter. The result, of course, was negative. Over the entire frequency range of the test transmitter from 160 kHz to 240 MHz we did not get any modulation. The experiment was repeated in the Physical Institute of the Aachen Technische Hochschule with their equipment, but even here no pronounced resonance point could be detected. Only very broad resonance ranges appeared.

By using two synchronized tape recorders, one of which was connected to the microphone probe and the other to the corona probe, we tried to make a comparison between the pressure variations and the migration of the ion cloud. However, these investigations are not yet completed. As for the resolution of the oscillograms, by using primitive means we succeeded in increasing this to the extent that a length along the abscissa of 1 mm corresponds to a time of $1/50,000$ second.

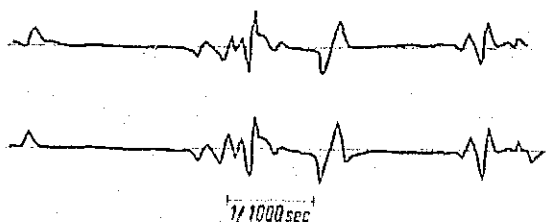


Fig. 10. Comparison of two tape recordings with corona probe under identical conditions.

Figs. 10 and 11 give some indication of the large possibilities offered by this method. Each of these figures involves two different tape recordings which were made under identical conditions. Just as with these examples, all of the oscillation pictures are clearly reproducible.

Note: We are very grateful to Dr. Raspet for his valuable advice and enthusiastic help in 1952 and 1953.

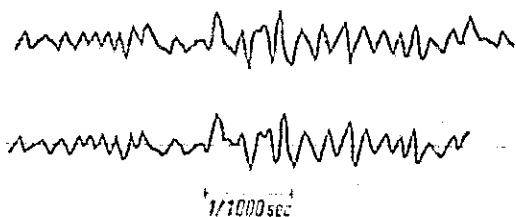


Fig. 11. Comparison of two tape recordings with corona probe under identical conditions.

Discussion

G.V. Lachmann, Ph.D. Eng. (London): Apparently no transition occurred at a small Reynolds number. Presumably what is involved, therefore, is a laminar bubble. That this occurs may be due to the fact that an American NACA profile was used. With similar profiles which were checked in England, a jagged pattern showed up in the pressure distribution which was missing in the American data. It was not noticed since fewer points were calculated. It may be that in his investigations Mr. van Nes was in the range of this zigzag pattern.

W. van Nes, M.S. Eng.: Measurements were made over the profile chord which showed the same effect everywhere.

Prof. A. Naumann, Ph.D. (Aachen): What was the surface material used?

W. van Nes, M.S. Eng.: Conducting and nonconducting material, aluminum and sprayed wood. The effect is independent of the surface material.

REFERENCES

1. van Nes, W., "Boundary layer measurements on a glider," Jahrbuch 1957 der WGL, pp. 281-286
2. Franzen, B., W. Fucks and G. Schmitz, "Comparison of corona and hot-wire anemometers by measuring turbulence spectra," Research Report no. 760 of Nordrhein-Westfalen, Westdeutscher Verlag, Cologne and Opladen, 1959.
3. Franzen, B., W. Fucks and G. Schmitz, "Corona anemometer for measuring turbulence components," Z. Flugwiss. 9, 347-351 (1961)